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POTENTIAL BIOLOGICAL IMPACTS OF NAVIGATION TRAFFIC

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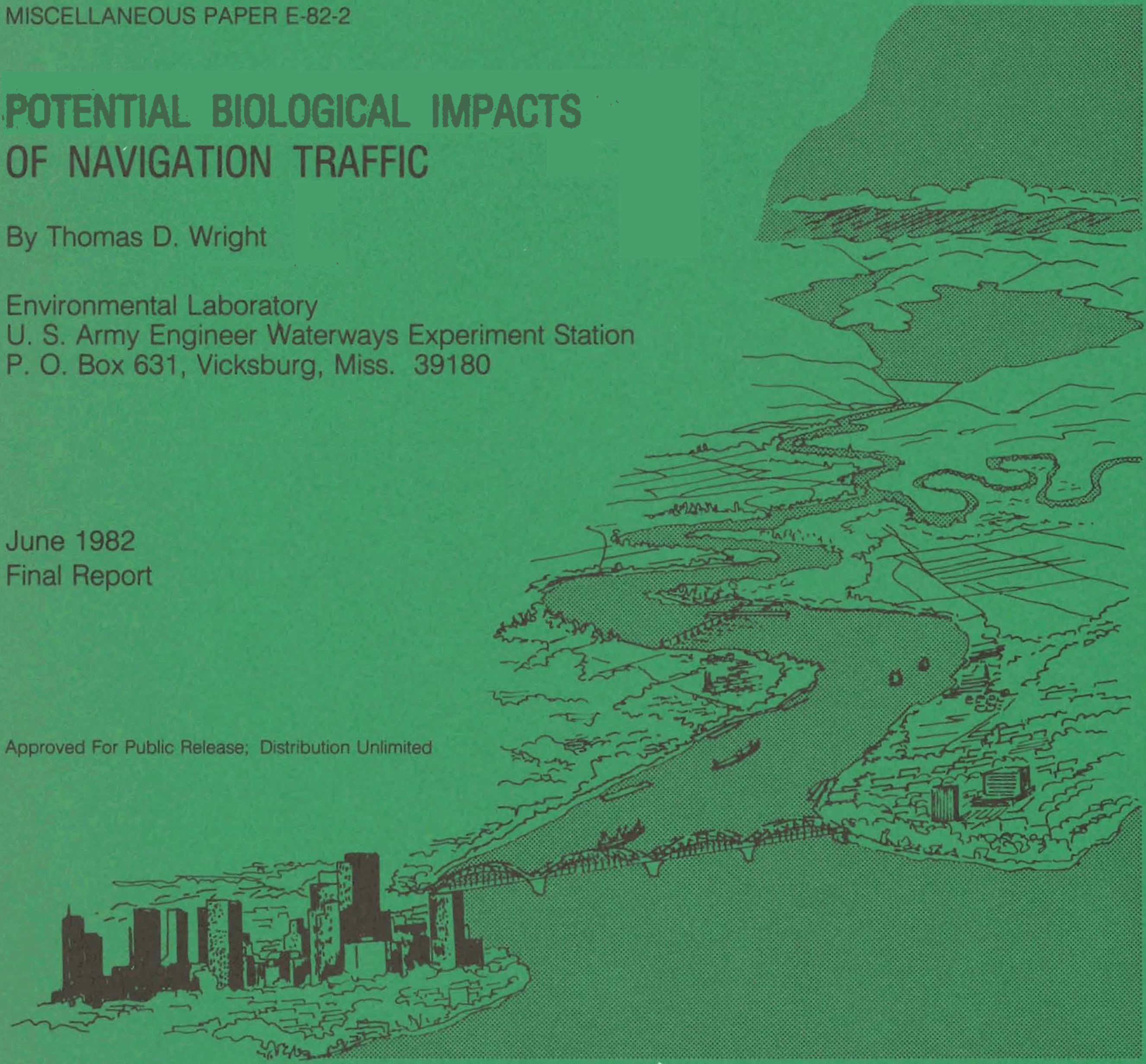

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A literature search was conducted to identify research relating physical and chemical changes associated with navigation traffic to potential biological impacts. It was found that, although some information on physical and chemical changes was available, documentation to demonstrate biological impacts was generally lacking. Where possible impacts were identified, they were observed at the organism level, rather than population, community, or ecosystem level.

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20. ABSTRACT (Continued).

A particular problem was encountered in attempting to separate impacts of navigation from those caused by natural and/or anthropogenic perturbations. It was concluded that biological impact analysis beyond the organism level may not be within existing state-of-the-art technology.

Preface

The following report was prepared at the request of the U. S. Army Engineer District, Mobile. It was one of several such reports intended to provide that agency with background information to aid in preparation of a Draft Supplemental Environmental Impact Statement for the Tennessee-Tombigbee Waterway, and it was included in that document as Appendix L.

The report is primarily a review of the scientific literature, although it refers to the waterway as a case in point. Because the report has potential general applicability to CE projects, it is being disseminated under the auspices of the Environmental and Water Quality Operational Studies (EWQOS) Program sponsored by the Office, Chief of Engineers (DAEN-CWO-M), and assigned to the U. S. Army Engineer Waterways Experiment Station (WES), Environmental Laboratory (EL).

The report was prepared by Dr. Thomas D. Wright, Chief, Aquatic Habitat Group, under the general supervision of Mr. Bob O. Benn, Chief, Environmental Systems Division, and Dr. John Harrison, Chief, EL. Dr. Jerome L. Mahloch was Program Manager of EWQOS. Preparation of this and related reports submitted to the Mobile District was coordinated by Dr. Wright. Technical manuscript review was provided by both Mobile District and WES personnel, and editorial review was provided by Ms. Dorothy P. Booth, EL.

The Commander and Director of WES during preparation of this report was COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

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Contents

POTENTIAL BIOLOGICAL IMPACTS OF NAVIGATION TRAFFIC

Introduction

1. Navigation traffic impacts upon physical, chemical, and biological variables have been a subject of debate for a number of years. Although the technology to estimate such potential impacts currently exists, only a limited effort has been devoted to their direct investigation. Whether or not such impacts are of sufficient magnitude to warrant serious concern at the population, community, or ecosystem level has not been decided. This is particularly true of biological impacts.

2. A partial reason for this information gap lies in the nature of the potentially impacted systems. These systems are, for the most part, large and highly dynamic. Hence, the possible effects of navigation traffic are apt to be masked or obscured by fluctuations that occur on both a short-term and a long-term basis. Such changes and events may result from natural or other perturbations and tend to be not readily separable from those resulting from navigation traffic. Even when it is possible to separate them, their meaning and importance beyond the individual organism level often remain unclear.

3. Most of the postulated biological impacts of navigation traffic appear to be secondary and indirect and would be caused by an alteration of the physical and chemical environment inhabited by the organism, population, or community of concern. An exception to this would be a direct biological impact such as an organism being struck by a vessel hull or a propeller.

4. To be classified as a biological impact, a particular event must meet certain criteria. For illustrative purposes, consideration of suspended solids provides an example. First it must be shown that navigation traffic causes a measurable change in suspended solids. This can only be determined by a comparison of ambient (background) conditions without traffic with those that are present with traffic. Secondly, it must be demonstrated that some biological component of the system which

could be affected by a change in suspended solids is present. This in itself often proves difficult because the biological components in a navigable system reflect the summation of all conditions existing in the system. It could be postulated that some organisms might be present in greater or lesser numbers or might inhabit different parts of the environment were not the observed changes in suspended solids shown to be resulting from navigation present.

5. The testing (acceptance or rejection) of the hypothetical impacts is most properly conducted under laboratory conditions rather than in the field. This is necessary to control other variables that may introduce spurious results leading to misinterpretation or erroneous findings.

6. In practice, this approach would require the establishment of control and experimental organisms in the laboratory. Conditions for the control groups of organisms should, so far as possible, simulate ambient (without navigation traffic) conditions as determined through field measurements. In the experimental group the same conditions, except for suspended solids, should prevail. Suspended solids (the experimental variable) should be established in such a manner as to simulate field observations on magnitude and duration. Both groups are then examined over an appropriate time period for evidence of effects. These effects might include longevity, reproductive success, growth, behavior, metabolic efficiency, etc. Should differences between the control and experimental groups be suspected from the observations, statistical techniques may then be employed to ascertain whether or not (and to what degree of confidence) the differences are real rather than attributable to chance.

7. This information would allow predictions to be made concerning the nature of impacts upon individual organisms that might reasonably be expected to result from changes in the concentration of suspended solids, but it cannot address all possible impacts or those potentially responsible for population, community, or ecosystem changes. For example, a change in suspended solids may render an organism more or less susceptible to predation; this could be evaluated only if appropriate predators

were present in control and experimental groups. In addition, the above approach does not provide information as to the underlying cause of the observed effects. A change in suspended solids may be associated with changes in other physical, chemical, or biological variables. As in nature, the organism will integrate all of these variables into an overall response pattern that tells the investigator what the response was, but probably will not suggest why. It is only with an understanding of why that extrapolation from one set of conditions to another is possible.

8. The rationale above sets the stage that the biologist faces in attempting to assess the potential impacts of navigation traffic upon changes in physical, chemical, and biological variables. There appear few, if any, systems where navigable and nonnavigable reaches exist in close proximity. If such could be found, there would exist the possibility that the two could be compared and effects determined under so-called "real-world" conditions. The same real-world conditions that allow commercial navigation commonly include dredging, river training structures, shoreline stabilization measures, industrialization, urban development, recreational navigation, increased agriculture, and other system perturbations. The impacts of these phenomena may greatly exceed or, at the very least, serve to obscure those attributable only to traffic.

9. Similarly, another commonly used approach, impact evaluation "before-and-after," appears to be inapplicable for navigation traffic. As noted, navigation traffic does not exist in a vacuum but is accompanied by a wide variety of other activities. These may serve to confound attempts to separate the impacts of traffic from those created by or associated with general regional development. A case in point concerns the Tennessee-Tombigbee Waterway (TTW). Although at first approximation it might seem that navigational development of this system might provide an opportunity to investigate "before-and-after" impacts of navigation traffic, detailed analysis of the problem suggests that it will be most difficult, if not impossible, to separate the direct impacts of traffic from those potentially associated with dredging, pooling by locks and dams, increased recreational traffic, etc.

10. Environmental and other considerations about the overall impacts of navigation led to the passage of Public Law (PL) 95-502, signed into law by President Carter in October 1978. Title I of this law directed the Upper Mississippi River Basin Commission (UMRBC) to develop a comprehensive master plan for the upper Mississippi River system. The master plan was to be developed in cooperation with appropriate Federal, State, and local officials, with a preliminary plan to be completed by 1 January 1981, and the master plan to be submitted to Congress by 1 January 1982. Section 101(e)(1) of the Act directed the Secretary of the Army and the Secretary of the Interior (through the UMRBC) to study the long- and short-term systemic ecological effects of present and projected navigation. A key element in this task was the investigation of navigation traffic impacts. The U. S. Department of the Interior was assigned as the lead agency and ultimately delegated this responsibility to the U. S. Fish and Wildlife Service.

11. The immediate result of PL 95-502 in the navigation impact arena was to initiate investigative studies on ecological impacts of navigation. In concept these studies were to elucidate, among other impacts, those attributable to navigation traffic. To this end numerous research contracts were initiated in 1980 to accomplish the task. At the present time the findings of this ambitious effort are, with a few exceptions, not yet widely available. A major exception consists of an information summary and annotated bibliography (Lubinski et al. 1981). This appears to be the most up-to-date survey of literature and state-of-the-art technology available on the subject. It should be noted that an earlier version of this document was subject to severe criticism (Hildrum 1980) and the current document has not yet been critically reviewed.

12. Lubinski et al. (1981) found that there were few studies to document the biological impacts of navigation. Out of over 900 references examined, only 56 were considered to be relevant. Of those 56, only 6 were felt to contain information pertinent to the effects of traffic (as opposed to dredging, locks and dams, shoreline stabilization, etc.). An examination of these six studies indicated that they were

largely judgmental and did not document actual observed biological impacts from navigation traffic.

13. Because of the paucity of documentation concerning known impacts, the remainder of this document will be largely judgmental. As noted earlier, virtually all potential biological impacts are mediated by physical and chemical changes. Hence the potential impacts have been divided into physical and chemical events that may cause biological changes, and there is no specific biological section. Their ordering is not indicative of their relative importance. It is important to recognize that most of the postulated impacts may very well be highly site specific. This is particularly true for those governed by such variables as depth of water, natural flow, or distance from the sailing line.

Discussion

Physical impacts

14. Turbulence. The passage of a vessel through the water creates turbulence because of hull friction and the action of the propeller, as well as displacement (Karaki and van Hoften 1974). It has been suggested by the Academy of Natural Sciences of Philadelphia (ANSP) (1980) that this turbulence may be sufficiently severe to kill or injure fish eggs, larvae and juveniles, and drifting invertebrate organisms. They point out that no knowledge exists concerning the direct impacts of turbulence upon these life forms.

15. The ANSP (1980) felt that in general turbulence did not pose a hazard to adult fish as these would be able to sense the approach of a vessel and would vacate the area. However, they cautioned that this may not be the case during winter conditions when fish tend to be sluggish.

16. Their overall considerations were based upon towboat traffic and did not take into account high-speed recreational traffic. Because of such factors as vessel speed and size, horsepower, propeller diameter and rpm, displacement, and frequency of passage, the induced turbulence from each type of vessel is probably quite different in degree and extent. Consequently, the impacts upon fish and drifting invertebrates

could well be different under these varying conditions.

17. The problem of turbulence, changes in current velocity, and possibly direct contact by the propeller and their relation to mortality of and injuries to aquatic organisms was considered to have a study priority of 9 (4 = minimum, 12 = maximum) by Lubinski (1980). For the upper Mississippi River he recommended that $498,000 over a 3-year period would be required to address the problem adequately. The recommended studies cited here and later by Lubinski (1980) and Bhowmik et al. (1980) do not describe how the work is to be carried out or its overall applicability.

18. Impingement. It was postulated by ANSP (1980) that fish and drifting invertebrates could suffer mortality or injury through being struck by propellers. As with turbulence, no data appeared to be available but ANSP felt that "a high direct mortality from adult fish being struck by tow propellers is not known and is not likely to noticeably deplete any species." Similarly, they stated, "the magnitude of the damage to the insect fauna within the area is not possible to determine; however, due to the relatively large size of the river and the narrow impact corridor (channel line), the effect would appear to be minimal." Most of their considerations in regard to turbulence are also applicable to impingement. Although not specifically stated in his document, Lubinski (1980) seems to imply that recommendations concerning turbulence and velocity change studies would also include impingement, as these could be investigated concurrently.

19. Suspended solids and sedimentation. Numerous studies have documented the impacts of suspended solids and their deposition (sedimentation) upon aquatic organisms. These impacts are almost always time-concentration related. While suspended, sediment may reduce the photosynthetic rates of planktonic and rooted submergent plants in instances where light is a limiting factor and may also clog or abrade the respiratory apparatus of aquatic organisms and interfere with activities such as reproduction and feeding. Upon deposition, these suspended solids may suffocate or bury organisms and may cause a loss of habitat through filling. These impacts tend to be generic in nature and are independent

of the source of suspension. Sources of suspension of particles include traffic, currents (gravity and wind induced), dredging, and organisms, especially bottom-feeding fish.

20. Numerous studies (Karaki and van Hoften 1974, Sparks 1975, Claflin 1976, Johnson 1976, Berger Associates 1980, and Environmental Science and Engineering 1981) have demonstrated that navigation traffic suspends sediment. These studies have led to estimates, for example, of the amounts suspended by discrete traffic events and the quantities which enter off-channel areas (Claflin 1976). Work by ANSP (1980) predicted the theoretical photosynthetic inhibition that might be expected to result from increased navigation on the Ohio River. Their results indicated that a projected traffic increase would reduce carbon fixation by 6 to 17 percent in the main channel during the summer months. This was estimated to amount to a reduction of less than 1 percent in total lentic productivity when the cross-sectional area was considered.

21. As discussed in the introduction, existing studies on the biological impact of suspended sediment and its deposition generally fail to separate those impacts attributable to navigation traffic from those resulting from other causes, so far as net ecosystem changes are concerned. Most studies have addressed discrete events and predicted inputs from these. Berger Associates (1980) concluded that:

> "During flood flows the Ohio River has the capacity to erode and transport sediment approximately 100 times greater than that which occurs during intermediate and low flows. The result is that most significant effects on both physical and biological systems occur during these episodic events. If it is assumed that the majority of changes that occur during low to intermediate flows are the direct or indirect results of navigation improvements or navigation use, then less than five percent of the total physical and biological impacts within the river basin would be referenced. Navigation-use-related physical and biological impacts are consequently imperceptible when compared to changes in bed, bank, islands, bars, habitats, and biota that occur during storms and major floods."

22. Many organisms are dependent upon the organic fraction (detritus) of suspended solids for sustenance. Cummins (1977) and

Vannote et al. (1980) have characterized larger rivers as heterotrophic systems. They postulate that allochthonous organic material rather than plankton is the primary energy source in such systems. Hence, minor reductions in photosynthesis may be relatively unimportant, and the suspension of solids may represent an augmentation of the food supply of iliophages (detritus feeders). There seem to be no data available to evaluate this possible contribution from solids suspended by navigation traffic as opposed to other sources.

23. Investigations of the biological impacts of suspended solids in the upper Mississippi River were given a priority of 11 (4 = minimum, 12 = maximum) by Lubinski (1980). This was the highest priority given to any study item. He estimated that these investigations would require an expenditure of $996,000 over a 6-year period.

24. Current velocity. Propwash and backflow are capable of creating or changing currents. The nature of these changes depends upon vessel speed, configuration, direction, depth, existing currents, and other factors. There have been a number of investigations of this phenomenon that have involved both empirical observations and models (Fuehrer and Romisch 1977, Berger Associates 1980, Environmental Science and Engineering 1981).

25. Many aquatic organisms require currents to exist and some are quite specific in these requirements. As examples, Engelhardt (1951) found that the net of a caddisfly collapsed in currents of less than 13 cm/sec but was burst by currents greater than 17 cm/sec, and Phillipson (1956) states that blackfly larvae are found within the range of 40 to 120 cm/sec with a peak abundance between 80 and 90 cm/sec. Similar information for other aquatic organisms exists in the literature.

26. The possible impact of changes in current velocity upon the biological community would most likely consist of the collapse or bursting of nets, a change of preferred habitats, and the dislodgement of organisms from the substrate. Dorier and Vaillant (1954) conducted field investigations of the minimum and maximum current velocities within which a variety of invertebrate organisms were found. They also determined the velocity at which these organisms were dislodged from the

substrate. Their findings were used by ANSP (1980) to predict the possible impacts of traffic-generated currents upon invertebrates in the Ohio River system.

27. Dorier and Vaillant (1954) suggested that backflow velocities appeared to be well within the known tolerances of most stream insects, but that propwash at some locations could potentially dislodge some species and burst the nets of others. They further postulated that downbound traffic could reverse the current direction for which the nets were constructed and that such reversal might possibly destroy or further damage the nets. They did not conduct studies to determine if actual dislodgement and/or net damage was actually occurring, and predicted minimal effects upon noninsect invertebrates.

28. One cannot be sure what dislodgement and/or net destruction represents to an individual organism or whether it constitutes a hazard for organisms that normally inhabit quiescent environments. It would almost certainly constitute an unnatural event. Considering the dynamic nature of most navigable systems and the perturbations of current velocity that they undergo through natural events, whether the traffic creates an unacceptable level of stress for these organisms is unknown. Even if it were known for individual organisms, any attempt to extrapolate to the population, community, or ecosystem level would be most difficult. As noted in the introduction, the question as to what the biota might be if traffic were not present remains unanswered and can probably never be answered because traffic is only one variable among many.

29. Investigations of the biological impacts of changes in current velocity in the upper Mississippi River were recommended by Lubinski (1980) in conjunction with those of turbulence (see paragraph 17 above).

30. Waves. Waves generated by the displacement of the water as a result of vessel passage were modeled 100 years ago by Froude (1881). These early efforts toward understanding waves were primarily directed toward reducing drag forces associated with wave generation to produce more efficient ships. Because of the potential of waves to cause erosion and damage to shore structures, most subsequent studies have been directed toward that consideration. Consequently, the mechanics and

energetics of waves are well understood; and, given appropriate information on physical and vessel factors, a reasonable predictive capability exists to describe the physical impacts of waves.

31. The potential biological impacts of waves have been summarized by Sparks (1975). He felt that wave action could have considerable impact on some of the most productive river areas, such as backwaters and littoral zones. These areas are important because they serve as nurseries for larval fish and are highly productive in terms of macroinvertebrates and plankton. Wave action may affect the fauna and flora in a variety of ways. Larvae and juvenile fish and macrobenthic organisms may experience stress from excessive wave action, and wave shock may actually knock them off plants and substrates, thus causing physical damage and exposing them to predation. The invertebrates may be more likely to be entrained in the drift along steep shorelines exposed to currents sufficient enough to sustain drift. Macrophytes may be uprooted by wave action and such conditions may make it difficult for future plant generations to remain in a given area. Sediment movement and resuspension by traffic may have an adverse impact by changing the habitat to the extent that it is no longer optimum or even marginally acceptable to some species. Turbidity induced by wave action may restrict the periphyton community or limit the euphotic zone and thus limit primary production. Settling of resuspended sediment fouls gills of fish and invertebrates, smothers eggs of animals, and restricts primary production areas of submerged vascular plants.

32. Lubinski et al. (1981) concurred with Sparks' (1975) summation but went further to state, "The magnitude and system-wide distribution of these impacts on the Upper Mississippi River System (beyond the fact that they are probably higher on the Illinois than the Mississippi River) are virtually unknown (emphasis added)."

33. As with many other possible impacts associated with navigation traffic, it is difficult to separate the biological impacts caused by navigation and wave action from those that may be attributed to waves from natural events. Berger Associates (1980) found that the effects of wind-induced waves are at least as great as those generated by the

passage of towboats, but they provided no quantitative information as to what these effects on organisms might be. Mueller (1980) found that nesting longear sunfish were disturbed by passing recreational traffic, but traffic that passed at speeds greater than 5 m/sec or more than 4.5 m away caused very few guarding males to abandon their nest. ANSP (1980) considered the possible impact of waves upon the emerald shiner and the longear sunfish (shore-zone spawners). It was their opinion that, considering the current success of these fish under existing conditions, it was not likely that they would be disturbed by projected increases in towboat passage.

34. Lubinski (1980) ranked studies of wave and drawdown effects on benthic, furbearer, and shoreline communities in the upper Mississippi River system as 9 (4 = minimum, 12 = maximum). He recommended the expenditure of $916,000 over a 4-year period to investigate wave impacts.

35. Drawdown. Drawdown from vessel passage may result in periodic exposure of varying duration of shoreline and backwater substrates. The magnitude of drawdown is related to vessel displacement, velocity, direction of travel, and midship cross-sectional area (Hurst and Brebner 1969). The ratio of vessel cross-sectional submerged area to river area is important, and in other than confined channel areas vessel-caused drawdown is negligible.

36. A potential biological impact resulting from drawdown is flushing action. Volumes of water containing plankton, larval fish, and some macroinvertebrates can be drawn from nearshore and backwater areas during drawdown. This may diminish backwater populations but may also be an important energy input to main-channel food webs.

37. Another possible impact of drawdown is the periodic exposure of the substrate. This may expose or strand a variety of organisms such as worms, fly larvae, mussels, and fish eggs. Single short-duration exposure (up to several minutes) may not be critical to the organisms, but prolonged periods of drawdown and frequent short-duration exposure may cause the organisms to perish. Some organisms can tolerate a wide spectrum of environmental conditions and may exist with drawdown while others may be less tolerant and perhaps eliminated.

38. As with waves, Berger Associates (1980) estimated the impacts of drawdown. Depending upon a number of variables (flow, vessel position, etc.) biological impacts were considered to range from zero to moderate but no quantitative information was given by Berger Associates. Moreover, it is not clear whether their evaluation considered changes in velocity, stranding, atmospheric exposure, displacement of organisms out of their normal habitat, etc. Likewise, Lubinski et al. (1981) commented that although drawdown can expose benthic organisms, the magnitude and distribution of this impact on the upper Mississippi River system have not been well documented.

39. It was the opinion of ANSP (1980) that the biological impacts of drawdown did not seem especially significant in the Ohio River. Studies by Environmental Science and Engineering (1981) on the Illinois and Mississippi rivers investigated the possible biological impacts of the reversal of river flow and offshore velocity components generated by tow passage. They found:

> "The unnatural offshore and onshore velocities will tend to transport sediments, detritus, larvae, and eggs alternately toward and away from the navigation channel. Any detrimental effects of this transport, however, are undetermined. The flow reversals may have a disorienting effect on certain species such as mussels that align with the current. However, the periods of reversal are so brief (approximately 2 minutes) that the impacts are probably minimal. The current reversals and surges may also damage food gathering nets of certain net spinning Trichoptera. The extent or net impact of such damage cannot be assessed from available data."

Their findings would seem to support those of other investigators that, although some physical impacts are identifiable and measurable, their biological impact is obscure.

40. Lubinski (1980) recommended that two studies concerning drawdown impacts be conducted on the upper Mississippi River system. Both were given a priority rank of 9 (4 = minimum, 12 = maximum). The first study would consider wave and drawdown effects on benthic, furbearer, and shoreline populations and would require the expenditure of $916,000 over a 4-year period. The second study would consider the impacts of

traffic-induced drawdown on the exchange of water, plankton, and organic material between the main channel and off-channel areas. This study was estimated to cost $309,000 over 3 years.

Chemical impacts

41. Dissolved oxygen. Navigation traffic can alter the dissolved oxygen (D.O.) concentration through several mechanisms. First, turbulence may increase D.O. by entrainment and exposure of the water to atmospheric oxygen. Second, reduced suspended solids, if present through traffic activity, may decrease D.O. by exerting an oxygen demand. Third, if light is limiting photosynthesis in the system and suspended solids should decrease light penetration in the photic zone, the reduced photosynthesis may reduce oxygen levels. Reduced oxygen levels are, of course, of concern as virtually all aquatic organisms require adequate oxygen supplies in their life activities.

42. Johnson (1976), in studying the effects of navigation traffic on the upper Mississippi River and Illinois River, noted that most of the time vessel passage did not alter D.O. concentrations. When an alteration was observed, it was small and increases were noted about as often as decreases. He also found that turbulence-induced reaeration or natural diel effects caused increases in D.O. that were greater than any observed decreases. He noted that his findings generally agreed with those of Sparks (1975).

43. Butts (1974) measured oxygen demand on the Illinois River and postulated that the resuspension of sediments by barge traffic might increase localized short-term oxygen demand by 7 or 8 fold. Johnson (1976), however, pointed out that Butts' (1974) prediction was based upon depletion measurements carried out in closed containers. The use of closed containers precluded any reaeration and led Johnson (1976) to suggest that the predictions of Butts (1974) were not highly credible.

44. In studies on the Ohio River concerning navigation traffic, Berger Associates (1980) found that "As a general rule dissolved oxygen changes resulted in an increase although it was temporary. By test completion (approximately 10 minutes) dissolved oxygen levels had returned to pretest values." Hence, it appears that if suspended solids from

navigation traffic exert any significant oxygen demand, this demand seems to be offset by traffic-induced reaeration. It is even possible that traffic may actually reduce the oxygen demand of sediments from that which would occur if the sediments were undisturbed. However, this reduced demand, through the increased oxidation of detritus, may serve to decrease the food resources available to organisms that consume detritus. As previously noted, there is evidence that the primary source of energy in many navigational river systems is from allochthonous sources rather than from direct primary production within the system (Cummins 1977, Vannote et al. 1980).

45. There appear not to be any specific data available regarding the reduction of photosynthesis and any concomitant reduction of D.O. through a decrease of light penetration as a result of navigation traffic. There are, of course, many general studies of photosynthetic inhibition in aquatic systems as a result of decreased light penetration. It could well be that any such reduction in navigable riverine systems would be obscured by that resulting from other causes, especially natural events. Garton et al. (1979), in reviewing the U. S. Environmental Protection Agency (1977) criterion that solids not reduce the depth of the photosynthetic compensation point by more than 10 percent from the seasonal norm, felt that the criterion was "...difficult to apply under most conditions and impossible in others." Although ANSP (1980) did not comment directly on possible reductions in D.O., their opinion that any photosynthetic reduction by navigation traffic would be less than 1 percent (cross-sectional area) would seem to suggest a similar implication with regard to D.O.

46. Chemical contaminants. The vast majority of chemical contaminants in oxic freshwater systems are sorbed onto particulate matter. Silts and clays have a greater ability to sorb contaminants than do coarser (sand) sediments. If these sediments should be suspended in the water column by navigation traffic, storms, dredging, or other events, a potential exists for desorption and solution of contaminants. Conversely, sediments may remove dissolved contaminants from the water column (Gustafson 1972). This phenomenon is governed by the nature of

the contaminant, the degree to which it adheres to particles, and solution equilibria (Patrick et al. 1977). In general, the biological availability (and hence the ecological significance) of most contaminants is much greater when they are in solution than when they are sorbed upon particles.

47. In addition to the resuspension of sediment being a potential source of contaminants, some have been shown to originate directly from navigation traffic. Jackivicz and Kuzminski (1973) estimated that in 1970 there were 7.2 million outboard motors in use and over 98 percent were 2-cycle type. They found that these motors discharged nonvolatile oil, volatile oil, lead, phenols, and raw fuel into the water. They reported that up to 55 percent of the original fuel could be discharged into the water with average values between 10 and 20 percent.

48. Chemical contaminants pose a potential hazard to aquatic life. They may cause direct mortality or chronic effects. Such possible effects will occur only if the contaminants are present in a bioavailable form to be taken up by organisms and if they persist in the environment of the organism above a given concentration-time tolerance.

49. Lubinski et al. (1981) postulated that the resuspension of contaminated sediments may result in contaminants being released into the solution. To evaluate such potential release in the Ohio River system, Berger Associates (1980) conducted standard sediment elutriate tests for a variety of metals. In all cases, observed values were below detection limits in both ambient and elutriate water. It should be noted that the sediments were relatively coarse. Coarse sediments characteristically have lower concentrations of contaminants than do fine sediments, but they also tend to release contaminants more readily than do fine sediments.

50. GREAT I (1979) investigated contaminant release from navigation traffic resuspension of sediments. Following the passage of the first towboat of the year through Lake Pepin (upper Mississippi River), they found that although the fine sediments were contaminated with metals, nutrients, and PCBs, "Release or dissolution of resuspended contaminants to the water column was not evident." In addition, they noted,

"Water quality impacts from subsequent barge tow passages were not discernible."

51. As the release of contaminants from sediments is a generic event, it is appropriate to consider information regarding activities other than navigation traffic. Following the 5-year comprehensive Dredged Material Research Program (DMRP), Saucier et al. (1978) summarized:

> "Turning to inland and coastal areas, the DMRP achieved definitive results that soundly substantiate that most widely held fears over the short-term release of contaminants to disposal site waters are unfounded. As long as the geochemical environment is not basically changed, most contaminants are not released from the sediment particles to the water. However, in contrast, upland disposal often does result in a change in the geochemical environment that can lead to contaminant release. Some nutrients such as ammonium and mangenese and iron are released in openwater disposal but in most cases enough mixing is present to rapidly dilute these to harmless concentrations. Situations where toxic effects could occur would most likely be where pipeline dredges are discharging large volumes of material into very shallow estuarine waters."

52. In the case of sediment resuspension and potential release of contaminants from such sediment, it is important to note that this would not result in a change in the geochemical environment. In order to have been present in the first instance, the sediments would need to have been carried in suspension from some other point in the system. The net impact of traffic, therefore, would seem merely to complement or augment natural events involving sediment transport. There would appear to be no plausible reason to believe that the resuspension of sediments by navigation traffic would result in any greater or lesser release of contaminants than would other transport mechanisms. If it should, and the contaminants are bioavailable, a biological impact is possible.

53. This, of course, does not preclude site-specific considerations. Where there are significant quantities of contaminants present in the sediment and these sediments are subject to resuspension, techniques are available to determine potential release and bioavailability. Where doubt exists, such techniques should be employed to obtain

information concerning possible biological effects. In addition, the relative contribution of such releases as a result of navigation traffic as opposed to those from other events requires consideration.

54. Nutrients. Essentially all of the considerations of chemical contaminants are applicable to nutrients. The principal biological impact of nutrient release is to stimulate primary productivity through the removal of nutrient limitations on phytoplankton and/or other aquatic plants. This increase in productivity may result in several problems. First, when the plants die, their increased biomass may deplete oxygen through normal oxidative processes. Second, changes in species composition may occur through succession and/or eutrophication. In some systems there may be a remote possibility that vegetation stimulated as a result of removal of nutrient limitations may actually impact navigation. At least one nutrient, ammonium, may also be toxic under certain conditions.

55. As noted in paragraph 51 above there is evidence for the release of ammonium from dredging. Ammonium is most uncommon in oxic environments, and it is unlikely that traffic would result in its release. In fact, traffic may decrease the amount of ammonium in bottom sediments by suspending and aerating the sediments and thus facilitating the biological conversion of ammonium to nitrite and/or nitrate. There are, however, examples of direct nutrient increases through navigation traffic. Yousef et al. (1978) found that turbidity, total phosphorus, total D.O., total organic carbon, and chlorophyll-a were increased through mixing by recreational traffic. It is not clear as to whether the total phosphorus was bioavailable. These increases were found to be dependent upon water depth, motor power, operational time, and the type of sediment present in the system.

56. It should be noted that nutrients, as with chemical contaminants, are rarely derived from the sediment. Rather, they enter the system from a variety of sources and are transported through the system in both dissolved and particulate forms by many mechanisms. Navigation traffic is but one of these mechanisms. As with many other variables and their potential biological impacts, the key to meaningful evaluation

of nutrients depends upon the determination that an impact actually exists and is important to the ecosystem and the degree to which it is directly caused by traffic.

57. Spills. Cargo spills may, depending on the nature of the cargo, have biological impacts. These impacts will obviously depend upon the substances involved, the biological community that is present, the extent of spread, the concentration of the spilled substances, and a number of other factors. All of these must of necessity be evaluated and/or predicted on a case-by-case basis.

58. Bhowmik et al. (1980) gave the study of chemical accidents a beneficial priority (as opposed to urgent or necessary). They estimated that $107,000 over 2 years would be required for investigations. Lubinski (1980) rated spills (and waste loading) from vessels as priority 7 (4 = minimum, 12 = maximum). He estimated that $237,000 over a 2-year period would be required to estimate biological impacts.

59. Vessel wastes. Very little information is available concerning chemical contributions from navigation vessels (see paragraph 47 above). Bhowmik et al. (1980) felt that fuel and oil leakage and spills are probably the most important and would tend to be more significant near marinas and docking and fueling areas. Cooling system contaminants and those from outboard motor exhausts were also considered. They placed this subject in the beneficial category (as opposed to urgent or necessary) and suggested that $124,000 would be required over a 5-year period.

60. Similarly, Lubinski (1980) rated this topic as a priority 6 item (4 = minimum, 12 = maximum) and estimated that an evaluation of biological impacts would require $237,000 over a 2-year period. These investigations would address spills as well as vessel wastes.

Summary

61. In spite of concern over the potential biological impacts of navigation traffic, there seem to be few studies that have conclusively demonstrated that such impacts actually exist. A critical problem in

analysis lies in separating the impacts of navigation traffic from those caused by natural and/or other anthropogenic perturbations, whether or not the latter are related to navigation.

62. A reasonable technology is currently in existence to evaluate physical and chemical impacts of navigation. Biological impacts can be measured at the organism level, but extrapolation to the population, community, or ecosystem level will prove very difficult. Investigations of the physical and chemical impacts are, however, much simpler than biological impacts because they tend to follow well-established laws and principles under a given set of conditions. For example, the force directed by various known current velocities upon sediment particles of a particular size yields both predictable and reproducible results.

63. This is rarely the case with biological impacts. Biological systems represent the integration of all physical and chemical conditions that exert an influence upon them. Unlike many chemical and physical systems where inverse relationships are the rule, biological systems tend to be governed by exponential relationships. Hence, in biological systems, it is virtually impossible to <u>do merely one thing</u>. Any particular action in a biological system or any impact upon it is apt to increase in magnitude rather than decrease as one moves away from the initial impact point.

64. Newton's law of universal gravitation verifies the poet Francis Thompson's observation that:

> "...Thou canst not stir a flower
> Without troubling a star."

It cannot be denied that every star in the universe, even those beyond the reach of the most powerful telescope, will have its position and motion altered by that action. The physical scientist makes little use of this fact because <u>practically</u> it is of no importance because these alterations are quantitatively beyond any ability to measure them.

65. Estimates of navigation traffic impacts have generally failed to take into account the exponential relationships and the inherent instability of all biological systems. Through constraints in time, funding, or perception, virtually all biological investigations have

failed to make the crucial and absolute link between a known and quantifiable physical and chemical event and a biological impact. Few reputable aquatic ecologists would disagree, for example, that suspended solids do indeed affect organisms. Nevertheless, this leaves the question of relative source contributions, relative impacts, and overall ecological significance unanswered.

66. It is possible that the studies conducted by the UMRBC under PL 95-502 may serve to quantify many biological impacts. Should they not or if their findings are shown to be inapplicable to other navigable systems, the unanswered questions will persist. Evidence of these unanswered questions is provided by studies suggested by upper Mississippi River researchers. They recommend that over $3,000,000 and up to 6 years are required in addition to the work conducted under PL 95-502. It is not clear how much of this effort will be directed toward the determination of whether a problem exists and how much to the actual investigation of impacts from a population, community, or ecosystem standpoint.

67. In essence then, there is extremely poor documentation of the possible biological impacts of navigation traffic although some physical and chemical changes have been identified. The relative contribution of navigation traffic to such changes is also not well understood in many cases but is amenable to resolution. Biological impact analysis beyond the organism level is a much more difficult problem and may be beyond existing state-of-the-art technology. Such analysis will require careful attention to problem identification, the establishment of priorities, and the allocation of adequate resources over an appropriate timespan.

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